

NOAA Research Strategic Plan for FY 2003- FY 2008 and Beyond

**Understanding Threats to Society and the Environment
from the Bottom of the Ocean to the Surface of the Sun**

U.S. Department of Commerce
National Oceanic and Atmospheric Administration
NOAA Research

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Foreword: The Role of NOAA Research in Emerging Agency Priorities.

State-of-the-art research has been identified as a major cross-cutting theme in the new NOAA Strategic Plan for FY 2003 to FY 2008, emphasizing the importance of a broad and generously supported research mission to better serve users. NOAA Research and its partners strive to understand and describe the global environment in support of the broad NOAA mission by executing a wide array of basic and applied research activities to enhance current services and achieve priority outcomes. The NOAA Strategic Plan, and this complementary plan for NOAA Research, lay out an ambitious plan for achieving these goals.

NOAA Research must balance its near-term responsibility to address the needs of NOAA and our stakeholders with our long-term commitment to conduct visionary research free from the demands of day-to-day operations and the pressures of regulation. This dual responsibility requires the transfer of research to operations, as well as continued exploration of the unknown and development of important new scientific ideas. Balance in a research program will yield the most benefits to our nation as sound science informs the policy debate around the most pressing issues.

The processes that drive weather, water, climate, oceans, and coastal cycles are interrelated and are, to an extent not yet precisely defined, influenced by human activities. Understanding these processes requires new interdisciplinary approaches. Each year, NOAA Research contributes to better understanding of the ocean's role in forcing climate variability and change and the role of changing climate on weather phenomena. Additionally, there is a new focus on ecosystem-wide approaches to understanding and addressing environmental problems, and to understand what the scientific disciplines – physical, biological, chemical, and social – tell us about how humans and natural systems interact.

Recent trends that shape the environmental, economic, social, and political climates have led to a more diverse set of users of NOAA Research information in fields such as homeland security, energy, climate, and solar weather. These users demand an increasingly specialized suite of products. Customer requirements are a significant driving force behind our research and outreach agenda. NOAA Research sets priorities based on current agency demands as well as on the anticipated and increasingly more complex societal and environmental needs. A key component of the NOAA strategic plan is the strategy to *Engage, Advise, and Inform*, representing our commitment to work with stakeholders, policy makers, and resource managers to identify pressing public policy concerns and to respond with relevant research agendas.

Some primary NOAA Research customers are internal NOAA service and operational programs. NOAA Research supports all of the NOAA line offices by providing a wide array of products from fisheries and aquaculture management tools and technologies for the National Marine Fisheries Service to forecasting tools for the National Weather Service. Working with NOAA customers and partners to inform the research agenda, and communicate crucial information on the physical and social systems that are most useful to decision-makers, is a key aspect of crafting good science policy.

Utilizing world-class technical capabilities, NOAA scientists and external partners support advancement of knowledge regarding key issues through long-term monitoring, assessments,

directed research, extension services, and stakeholder interaction. NOAA Research partners provide additional scientific and technical expertise necessary for NOAA to carry out its mission. In order to maximize resources and address complex problems, partnerships are essential to advance research. Partnership interactions span a wide range of relationships including formal and informal relationships with other federal agencies, universities and academia, the private sector, state, local and tribal governments, and the international community. A recent internal review recommended that fifty percent of new NOAA funding for research be made available to our external partners.

Dedication to research and development activities is essential for answering complex and interrelated scientific questions and for meeting the goals identified in the NOAA Strategic Plan. The strategic plan for NOAA Research represents our commitment to build on our history of success and to tackle the challenges NOAA faces in a changing global environment.

Louisa Koch
Acting Assistant Administrator
NOAA Research

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Vision

Societally relevant research that forms the scientific basis for more productive and harmonious relationships between humans and their environment.

Mission

To conduct research, develop products, provide scientific understanding and leadership and to conduct outreach towards fostering NOAA's evolving environmental and economic mission.

INTRODUCTION

Strategic Planning for NOAA's Future:

NOAA sees strategic planning as a dynamic process that is modified annually to ensure appropriate intermediate objectives meet its major mission goals. The process drives budget formulation by encouraging strategically planned initiatives to meet the mission goals in this plan.

NOAA has adopted four major **Mission Goals** beginning in FY2003.

1. Protect, Restore, and Manage Use of Coastal and Ocean Resources through Ecosystem-based Management
 - a. Objective A: Protect, Restore, and Manage Use of Ocean, Coastal, and Great Lakes Resources
 - b. Objective B: Recover Protected Species
 - c. Objective C: Rebuild and Maintain Sustainable Fisheries
2. Understand Climate Variability and Change to Enhance Society's Ability to Plan and Respond
3. Serve Society's Needs for Weather and Water Information
4. Support the Nation's Commerce with Information for Safe, Efficient and Environmentally Sound Transportation

Each of the mission goals is organized on an outline of five common **Mission Strategies**. In this plan, how NOAA Research and its partners will meet the four mission goals are described under each strategy. The strategies are:

Monitor and Observe the land, sea, atmosphere, and space, and create a data collection network to track Earth's changing systems;

Understand and Describe how natural systems work together through investigation and interpretation of information;

Assess and Predict the changes of natural systems and provide information about the future;

Engage, Advise, and Inform individuals, partners, communities, and industries to facilitate information flow, assure coordination and cooperation, and provide assistance in the use, evaluation, and application of information; and,

Manage coastal and ocean resources to optimize benefits to the environment, economy, and public safety.

Supporting the services and mission goals are **Cross-Cutting Priorities**. These priorities describe the programmatic and managerial underpinnings that facilitate NOAA's delivery of services and enable

effective operations. Each priority supports the Mission Goals and has its own measures of performance in the NOAA Strategic Plan. They are:

- C Sound, Reliable, State-of-the-Art Research
- C Integrated Global Environmental Observation and Data Management System
- C Homeland Security
- C Environmental Literacy, Outreach, and Education
- C International Cooperation and Collaboration
- C Organizational Excellence: Leadership, Human Capital, Facilities, Information Technology, and Administrative Products and Services

Performance Measurement at NOAA:

With the development of its new strategic plan, NOAA charged its organizational elements to develop targets for agency-wide accountability for achieving desired results as outlined in the NOAA plan. Following this, NOAA organizational elements, including NOAA Research, have initiated an ongoing process to track performance beginning with the evaluation of existing and the creation of new performance metrics as necessary to create a suite of suitable metrics matching priorities in the NOAA plan.

NOAA defines a **Performance Measure** as a description of a concept or a focus area for monitoring improvements toward a goal or objective. **Performance metrics** are the quantification of the measure and include a baseline and target goal.

NOAA intends to track performance metrics as listed in each of the NOAA line office strategic plans. Emphasis is on the establishment of current agency baselines followed by periodic assessment of progress toward reasonable targets. For reference, listed in the body of this plan are relevant Performance Measures from the NOAA strategic plan to which NOAA Research leads and/or contributes. A table of Performance Metrics, many of which are still under development, is attached to this plan as Appendix A.

At present, not every NOAA Performance Measure listed in this plan has a corresponding Performance Metric for tracking performance in each area. NOAA Research intends to develop Metrics for all of the NOAA Measures.

MISSION GOAL 1. PROTECT, RESTORE, AND MANAGE THE USE OF COASTAL AND OCEAN RESOURCES THROUGH ECOSYSTEM-BASED MANAGEMENT

Coastal marine areas, including the Great Lakes, are among the most affected by human development in the Nation. With more than half of our population residing within less than one-fifth of the land area in the contiguous United States, coastal counties are growing three times faster than counties elsewhere, adding more than 3,600 people per day. The value added to the national economy by the commercial fishing industry is more than \$28 billion annually, and more than 18 million Americans engage in marine recreational fishing every year. Coastal waters support more than 28 million jobs, generate more than \$54 billion in goods and services, and provide a tourist destination for 180 million Americans each year. NOAA Research long-term coastal and ocean research planning reflects assessment and prediction of the effects of increased population and commerce along the coasts and Great Lakes and supports the management goals of other NOAA line offices, especially the National Marine Fisheries Service and National Ocean Service.

Relevant NOAA Outcome Measures

- C Increased number of coastal and marine ecosystems maintained at a healthy and sustainable level.
- C Increased social and economic value of the marine environment and resources (e.g., seafood, recreation, and tourism).
- C Increased number of acres and stream-miles restored for coastal and ocean species.
- C Increased number of protected species in a stable condition or an upward trend.
- C Increased number of managed species that are at optimum levels.
- C Improved ecological conditions in coastal and ocean protected areas.

OBJECTIVES AND STRATEGIES

Goal-Wide Ecosystem Strategy:

NOAA Research and its partners will provide essential scientific information to enhance the identification, assessment, understanding, and prediction of environmental threats to ecosystem health including physical, chemical, and biological functions in support of comprehensive ecosystem management. The primary focus is to improve the understanding of ecosystems, identification of regional ecosystems, and the development of ecosystem health indicators, including model development to improve forecasts of characteristics of the ocean, coastal, and Great Lakes systems. The majority of research and outreach by NOAA Research related to NOAA Mission Goal 1 supports the Goal-Wide Ecosystem strategy.

Relevant NOAA Performance Measures:

- C Increased number of regional ecosystems identified and monitored with agreed-to indicators of ecosystem health (OAR supporting).
- C Increased number of ecosystems where ecological functions and links to human activities and impacts are adequately understood for management purposes (OAR supporting).
- C Increased number of models linking climate/weather/atmosphere with ecosystem/hydrology made operational to assess and predict natural and human-induced changes in the coastal and ocean environment (OAR lead).
- C Increased number of coastal, ocean, and Great Lakes areas (including coastal watersheds) with Federal, state, and local government or non-governmental management plans using ecosystem best management practices and approaches (OAR supporting).

Objective A: Protect, Restore, and Manage Use of Ocean, Coastal, and Great Lakes Resources

Monitor and Observe: NOAA Research will develop and expand the technological basis for coastal and Great Lakes observation systems and networks as well as automated data collection devices to provide

better, more cost effective monitoring of coastal and ocean habitats and resources. Priority areas include understanding the links between climate change and/or ecosystem health; expanding the use of new technology, such as lidar for long-term ecosystem monitoring including monitoring marine debris; increasing the time series from cabled and autonomous underwater hydrophone systems for deep sea observations; increasing the scientific studies associated with observation systems and networks; and, to monitor and observe coral reef health in conjunction with the Coral Matrix-managed program.

Relevant NOAA Performance Measures:

- C Increased area covered and number of ecological conditions monitored by state-of-the-art observation systems and platforms that provide necessary information for NOAA's stewardship responsibilities (OAR supporting).

Understand and Describe: NOAA Research will conduct research to understand and describe coastal, ocean, and Great Lakes resources and the human impact on those resources in support of ecosystem management. Observations will help quantify the contribution of atmospheric deposition of pollutants to coastal ecosystems as well as the impact of weather-related events on ecosystem health.

Additionally, NOAA Research and its partners will characterize and assess coastal and ocean resources through exploration, mapping and researching of unique habitats and their associated organisms within the U.S. Exclusive Economic Zone, such as shallow and deep water corals, hydrothermal vents, and methane hydrates. NOAA Research will develop new tools and techniques in ecosystem forecasting, exploration, research and aquaculture to facilitate understanding and use of marine resources. New tools and technologies such as Autonomous Underwater Vehicles, sea floor observatories, underwater laboratories, and chemical, physical, and biological sensors will aid underwater in situ, long-term exploration and research of the ocean, coastal, and Great Lakes systems. Research may also reveal previously unidentified natural products that can be extracted from marine organisms for potential pharmaceutical or industry application.

Relevant NOAA Performance Measures:

- C Increased coastal, ocean and Great Lakes areas explored, mapped, characterized, and inventoried (OAR supporting).
- C Increased number of affected human communities where sufficient data exist to analyze and understand the economic and social benefits, costs, and impacts of management decisions (OAR supporting).
- C Increased number of techniques and tools that can be used to restore and protect ocean, coastal, and Great Lakes resources (OAR supporting).
- C Increased number of marine resources potentially available for commercial use (e.g., pharmaceuticals, aquaculture species for human uses) (OAR lead).

Assess and Predict: NOAA Research will build environmental forecasting systems that improve safety and contribute to both ecosystem health and the economy for all coastal residents. Priority areas for ecosystem forecast improvements include climate change, land-based and atmospheric pollution, and invasive species introduction. For example, NOAA Research will increase the accuracy of models to detect and forecast climate change effects, such as water levels, on coastal and Great Lakes ecosystems, as well as the accuracy of circulation models for predicting the transport and fate of land-based pollutants in the Great Lakes and coastal waters. It will increase the number of models that incorporate atmospheric pollution loadings of nitrogen and mercury and their impact on ecosystem health (i.e. harmful algal blooms). Finally, it will improve the forecast of invasive species introduction and associated impacts on marine and Great Lakes ecosystems, including the implications for fish populations.

Relevant NOAA Performance Measures:

- C Increased number and accuracy of forecasts of significant ecological events and trends (e.g., harmful algal blooms, coral bleaching, and population shifts) (OAR supporting).
- C Increased number and accuracy of models to understand and predict the interactions of species with their environments (OAR supporting).

Engage, Advise, and Inform: NOAA Research fosters understanding and integration of scientific information into considerations of national environmental issues and enhances the public's science literacy and problem solving by conveying scientific discoveries as they are made. It seeks to develop technology transfer and education programs to spearhead and/or assist NOAA outreach efforts related to priority issues. NOAA Research supports an extensive collaborative extension program as a mechanism to leverage NOAA's outreach capabilities.

Relevant NOAA Performance Measures:

- C Increased percentage of coastal communities and coastal inhabitants aware of, and acting appropriately to minimize, their impacts on coastal, ocean, and Great Lakes resources (OAR lead).

Manage: The results of NOAA Research provide essential input for effective management of fisheries, invasive species, and coastal, ocean, and Great Lakes ecosystem health. NOAA Research will develop effective management techniques to control the impacts of invasive species on water quality, habitat, food web structure, and ecosystem structure and function. Invasive species management requires us to focus not only on control and eradication of already established species but, perhaps more important, on prevention and rapid response to minimize the risk of future introductions. A primary focus is the development of practical ballast water technology that meets future removal standards because ballast water has been identified as the primary vector for the spread of non-indigenous aquatic species. Additionally, NOAA Research will increase ocean fisheries production through offshore technology development for environmentally sound aquaculture.

Relevant NOAA Performance Measures

- C Increased number of invasive species under control (OAR lead).
- C Increased ocean fisheries production through environmentally sound aquaculture (OAR supporting).

Objective C: Rebuild and Maintain Sustainable Fisheries

Understand and Describe: NOAA Research will conduct scientific investigations to limit the effects of habitat destruction and by-catch, foster the development of environmentally responsible mariculture, identify, and describe ecological features of fisheries biology and habitat to support management of marine fisheries by NOAA Fisheries, and conduct scientific investigations to determine the efficacy of conservation techniques, including Marine Protected Areas and National Marine Sanctuaries. New tools and technology for increased accuracy of fish stock assessment and by-catch reduction, combined with improved stock enhancement technologies and descriptions of essential fish habitat and emerging diseases for economically important fish species, will help replenish fisheries stocks. Additionally, NOAA Research will sponsor aquaculture technology development and associated research on potential environmental impacts to underpin efforts by NOAA Fisheries to create a regulatory framework for marine aquaculture and also to enhance fisheries stocks.

Relevant NOAA Performance Measures:

- C Increased number of fish species where the biological and ecological factors related to population abundance are adequately understood for management purposes (OAR supporting).
- C Increased number of fish species that habitat or other environmental conditions are adequately understood for management purposes (OAR supporting).

- C Increased number or adequacy of techniques and tools that can be used to restore and conserve fish species (OAR supporting).

Assess and Predict: NOAA Research will conduct research with an emphasis in understanding the role of essential fish habitat. This will include identifying habitat requirements for healthy populations, assessing the damage from mobile fishing gear, and providing research results that increase management's ability to identify, protect, and restore essential fish habitat.

Relevant NOAA Performance Measures:

- C Increased number of fish species whose essential fish habitat is adequately mapped and understood (OAR supporting).
- C Increased use of physical-biological models for forecasting physical stock abundance (OAR supporting)

Engage, Advise, and Inform: NOAA Research will conduct research and outreach to help the seafood industry practice safe seafood handling for increased safety. The knowledge will be transferred to resource managers to decrease cost, add value, ensure high-quality and safe products, and improve waste management for seafood.

Relevant NOAA Performance Measures:

- C Increased number of NOAA technologies and techniques that have been transferred for appropriate resource use and managed species conservation to state and local managers, as well as to the public (OAR supporting).

MISSION GOAL 2. UNDERSTAND CLIMATE VARIABILITY AND CHANGE TO ENHANCE SOCIETY'S ABILITY TO PLAN AND RESPOND

The sharp rise in demand for climate information to be used in decision-making drives our research agenda to improve knowledge of the mechanisms that control our climate and to better understand the human-climate interface. From mitigation of natural hazards and climate-driven human health risks to improved water resource, forest, and ecosystem management, NOAA Research advances climate science around questions most relevant to our society and economy.

Seasonal and interannual variations in climate, such as El Nino, can lead to economic impacts of about \$25 billion to the U.S. economy. Improved climate forecasts can aid decision-makers across a wide variety of industries such as energy and water management. On longer timescales, the question of climate change superimposed on population growth with its increasing demands on finite environmental resources is a capstone issue for our generation. NOAA supports the national effort, led by the Climate Change Science Program, to provide the best scientific basis for understanding the factors forcing climate change and society's options for responding.

Relevant NOAA Outcome Measures:

- C Increased use and effectiveness of climate information to improve long-range (seasonal to intraseasonal) climate, weather, and water predictions (OAR lead).
- C Increased use and effectiveness of climate information for decision makers and managers (OAR lead).
- C Increased use of the knowledge of how climate variability and change affect commerce (OAR lead).

STRATEGIES:

Monitor and Observe: NOAA Research will improve climate observations, monitoring, and data management by strengthening our ocean, polar, and atmospheric research observations. The distribution, frequency, and kind of observations are driven by specific scientific questions related to climate change. More specifically, NOAA Research will increase the number and improve the quality of long-term observations of trace gases and other climate-forcing agents collected, archived, available, and accessible where random errors and time-dependent biases have been assessed and minimized; increase the availability and improve the quality of atmospheric and oceanic observations for operational products; and, produce global re-analysis for climate diagnostics, climate change detection, attribution, and assessments.

Relevant NOAA Performance Measures:

- C Increased number of long-term observations collected, archived, available, and accessible where random errors and time-dependent biases have been assessed and minimized. (OAR lead).

Understand and Describe: NOAA will work with national and international partners to increase understanding of the dynamics and impacts of the coupled atmosphere-ocean-land system through research on climate variability and change. Focus is on reducing uncertainty in estimates of the climatic impacts of aerosols, carbon, and stratospheric and tropospheric ozone; the evaluation of feedbacks in forcing climate; and, the effect of climate processes on the Earth's surface, including marine ecosystems.

NOAA Research will conduct process studies to achieve new and improved physical descriptions of climate processes and carbon measurement methods for prediction and projection models; improve modeling of the coupling of the atmosphere with the Earth's surface (land, ocean, cryosphere); extend understanding of the impact of climate variability and change on intraseasonal to interseasonal time

scales; characterize the factors that will determine the recovery of the stratospheric ozone layer; and, contribute to a seamless suite of products and services by filling the gap between weather and climate forecast techniques.

Relevant NOAA Performance Measures:

- C Improved and more precise descriptions of new research findings and progress toward their implementation into NOAA operations (OAR lead).
- C Decreased degree of uncertainty of climate system processes, including radiative forcing, in climate forecast products (OAR lead).

Assess and Predict: NOAA Research will improve forecasts to enable regional, national, and international managers to plan better for the impacts of climate variability and change and will provide improved regional, national, and international assessments to improve understanding of climate impacts and potential adaptation and mitigation measures in the context of multi-resource management and sustainability.

More specifically, NOAA Research will improve skill and capability in climate variability forecasts; expand participation in and the significance of NOAA contributions to the Intergovernmental Panel on Climate Change (IPCC) Working Group I, Climate Science, and in the Scientific Assessments of Ozone Depletion; and, improve accuracy in estimates of the contribution of non-carbon cycle constituents to climate forcing and in the estimation of U.S. terrestrial and global oceanic carbon sinks.

Relevant NOAA Performance Measures:

- C Improved skill of climate variability forecasts (OAR supporting).
- C Increased number, accuracy, and regional specificity of U.S. climate, water, and coastal resource products (OAR supporting).
- C Reduced uncertainty regarding long-term climate projections, as measured through improvements in climate change models and increases in the range of their application (OAR lead).
- C Increased involvement of NOAA researchers and use of NOAA scientific results in national and international assessments (OAR lead).
- C Reduced uncertainty in the estimation of the U.S. terrestrial and oceanic carbon sinks (OAR lead).
- C Increased number of new indicators of climate impacts on marine ecosystems (OAR lead).

Engage, Advise, and Inform: NOAA Research will meet increasing national demands for integrated climate information products and services by converting research advances in a way that supports practical applications. Research to operations will be achieved by supporting regional decision-support mechanisms and producing products for climate analysis and observational studies.

Relevant NOAA Performance Measures:

- C Increased volume of NOAA climate data and information used (OAR lead).
- C Increased number of new instances where NOAA information is integrated into decision-support and management systems, including fishery management plans (OAR lead).
- C Increased user satisfaction, determined through surveys (OAR lead).

MISSION GOAL 3. SERVE SOCIETY'S NEEDS FOR WEATHER AND WATER INFORMATION

On average, hurricanes, tornadoes, tsunamis, and other severe weather and ocean events cause \$11 billion in damages annually in the U.S. These events are directly linked to public safety, and about one-third of the U.S. economy (about \$3 trillion) is weather sensitive. With so much at stake, NOAA's role in observing, forecasting, and warning of high-impact weather and climate events is expanding, and economic sectors are becoming increasingly sophisticated at using NOAA's weather, air quality, and water information to improve their profits and their management of environmental resources. NOAA Research conducts sound science and enhances the NOAA capability for providing integrated observations, predictions, and advice for decision makers to manage many aspects of environmental resources—from fresh water, coastal ecosystems, high-impact weather, including space weather, to air quality.

Relevant NOAA Outcome Measures

- C Increased accuracy and amount of lead time (by category of storm type) (OAR supporting).
- C Increased satisfaction with and benefits from NOAA information and warning services, as determined by surveys of emergency managers, first responders, resource managers, industry, government, and the public (OAR supporting).

STRATEGIES:

Monitor and Observe: NOAA Research will invest in the development of new, cost-effective observational technologies and integrated weather observing systems that meet diverse and expanding societal needs for accuracy, increase the number of parameters observed, and expand temporal and geographic coverage. It will reduce the uncertainty in predicting high-impact weather and water events by integrating, calibrating, and validating radar, satellite, and other airborne and ground-based observing systems data/products for use in numerical and diagnostic forecast systems.

Relevant NOAA Performance Measures:

- C Increased observations obtained and used from partners, both international and domestic (OAR supporting).
- C Increased observations archived, available, and accessible (OAR supporting).
- C Increased number of new multi-use observing systems deployed (OAR supporting).
- C Improved effectiveness of NOAA's observing systems (OAR supporting).

Understand and Describe: NOAA Research will invest in the research and development of new technologies, techniques, and weather and water forecast modeling. The primary goal is to transfer useful techniques and technologies to support the National Weather Service operational forecasting. It will increase investments in joint projects with operational components to move research results and technological advances into operations. Priority areas include increased validation and improved performance of weather and air quality prediction models as well as creating a seamless suite of products and services that fill the gap between weather and climate forecast techniques.

Relevant NOAA Performance Measures:

- C Increased number of modeling advances by government and academia into the NOAA operational prediction suite (OAR lead).
- C Shortened cycle times from research (government and academic) to operations (e.g., models, technology, and techniques) through the use of testbeds and other methods (OAR lead).
- C Improved accuracy of weather and air quality prediction models (OAR lead).
- C Increased number of new research findings and progress toward their implementation in NOAA operations (OAR lead).

Assess and Predict: NOAA Research will demonstrate and transition new technologies and models to provide improved weather, water, air quality and space weather forecasts. It will improve the use of observations through data assimilation; assess and validate prediction models for weather, water, and air quality; improve information technology used by NOAA operations (e.g. Advanced Weather Interactive Processing System) and by other organizations (e.g. emergency managers); and, develop advanced computing technology and techniques for geophysical prediction. NOAA Research will also mitigate tsunami hazards to threatened coastal communities.

Relevant NOAA Performance Measures:

- C Increased use of observational data for verification of and assimilation into weather, ocean, water, and climate prediction models (OAR supporting).
- C Increased volume of forecast and warning information formatted to clarify the uncertainty of an event (e.g., space weather, and water and weather forecasts) (OAR supporting).
- C Improved performance of NOAA's weather and water, air quality, and space weather prediction suite (OAR supporting).

Engage, Advise, and Inform: NOAA Research will engage current and potential users of weather, water, air quality and space weather information to identify future needs. It will expand the use of space weather products by responding to the requirements of users of space weather information through stakeholder interactions and working to meet the identified requirements.

Relevant NOAA Performance Measures:

- C Increased number of communities with plans to act on weather warnings and to reduce the impacts of coastal hazards (OAR supporting).
- C Increased assistance to international partners to improve response capabilities to weather and water predictions (OAR supporting).

MISSION GOAL 4. SUPPORT THE NATION'S COMMERCE WITH INFORMATION FOR SAFE, EFFICIENT, AND ENVIRONMENTALLY SOUND TRANSPORTATION

Waterborne cargo contributes more than \$740 billion to the U.S. gross domestic product and creates employment for more than 13 million citizens. Improved surface forecasts and specific user warnings would likely reduce the 7,000 weather-related fatalities and 800,000 weather-related injuries annually in the U.S. from vehicle crashes. Better aviation weather information could significantly reduce the \$4 billion that is lost through economic inefficiencies caused by weather-related air traffic delays. NOAA's information products and services are essential to the safe and efficient transport of goods and people at sea, in the air, and on land. NOAA Research supports NOAA's delivery of transportation-related products.

Relevant NOAA Outcome Measures

- C Increased use and effectiveness of environmental information for planning for marine, air, and surface transportation systems (OAR supporting).

STRATEGIES:

Monitor and Observe: NOAA Research will observe and monitor the state of the atmosphere and the coastal, ocean, and Great Lakes environment and invest in the development of new observational technologies and integrated weather observing systems to support marine, aviation, and surface transportation weather forecasting.

Relevant NOAA Performance Measures:

- C Increased reliability, frequency, and use of marine, aviation, and surface transportation-related observations (OAR supporting).

Understand and Describe: NOAA Research will invest in the research and development of new weather and ballast water techniques and technologies as well as weather forecast modeling. Joint projects with operational components of NOAA to move research results and advances in technology into operations will be priority investments. NOAA Research will develop and improve data assimilation and data processing technologies, and improve the representation of physical processes in numerical forecast models to support surface, marine, and aviation transportation. Further, it will sponsor ballast water technology development with the goal of increasing the percentage of ships for which practical ballast water technology are available that meet removal standards to be determined.

Relevant NOAA Performance Measures:

- C Shortened cycle time from research (government and academia) to operations (e.g., new techniques, improved products) (OAR lead).
- C Increased capabilities of data acquisition technologies, processing, and analysis (NOS lead).
- C Development of viable alternatives to ballast water exchange to prevent the introduction of exotic species into U.S. coastal waters (OAR lead).

Assess and Predict: NOAA Research will demonstrate and transition new technologies and models to provide improved weather forecasts to support decisions on aviation, marine, and surface transportation. It will improve the detection of hazardous weather and improve short-range weather predictions of surface, marine, and aviation transportation hazards through model development and technology demonstration.

Relevant NOAA Performance Measures:

- C Increased accuracy and use of weather and marine forecasts to increase delivery, reliability, and efficiency of all land, water, and air transportation systems (OAR supporting).

CROSS-CUTTING PRIORITIES

NOAA Research is an integral member of the teams working to implement the six cross-cutting priorities below, as identified in the NOAA Strategic Plan. Further, it is the lead line office for ensuring “Sound, State-of-the-Art Research” throughout NOAA. Below are strategies and measures of success for the “Research” cross-cut followed by brief descriptions of how NOAA Research will support the other five.

Sound State-of-the-Art Research

At NOAA, science is driven by defined needs; informs management decisions; provides tools for environmental assessments, prediction, and management; improves products, services and management techniques; and enables society to anticipate changing social and economic needs. A balanced portfolio of short- and long-term research and technology development is necessary to maximize the effectiveness of the agency in delivering science solutions.

NOAA Research supports high-quality research as a foundation of its environmental analysis, prediction, and ecosystem management missions. It will develop and implement the new products, services, and approaches to ecosystem management needed by a Nation facing critical environmental, economic, and public safety challenges. NOAA Research staffs the NOAA Research Council and appoints a representative to sit on the Council. The representative will work on the Council and with the NOAA Science Advisory Board to accomplish the strategies for “Sound, State-of-the-Art Research” outlined below.

In general, NOAA Research will encourage innovative new discoveries, findings, technologies, and applications by NOAA Research scientists and its partners by promoting financial health and a strong workforce within the organization while enhancing external partnerships by increasing the percentage of new research funds that are made available to the external research community and working with them to identify new needs for research and to promote educational development.

STRATEGIES:

1. NOAA will increase its investments in short- and long-term research and in development of advanced technology to understand, describe, and predict changes in the natural environment.

Relevant NOAA Performance Measures:

- C Recognized high standards by researchers and decision makers for utility, objectivity, and integrity (OAR lead).
- C Increased number of recognized new discoveries, findings, or applications (OAR lead).
- C Increased accuracy in predictions and assessments (OAR lead).

2. NOAA will accelerate the transfer of knowledge and technology into operational use and ecosystem management.

Relevant NOAA Performance Measures:

- C Increased interactions among NOAA researchers, operational components, and resource managers to identify operational and policy needs (OAR lead).
- C Increased use of models and assessments among scientists, economists, social scientists, operational components, and ecosystem managers inside and outside NOAA (OAR lead).
- C Increased transfer of NOAA models, forecasts, products, and services from research into operations and ecosystem management (OAR lead).

3. NOAA will strengthen external partnerships and increase interactions by ensuring that 50% of new research funds are spent within the external community (e.g. university, private sector) via competitive proposals and peer review.

Relevant NOAA Performance Measures:

- C Increased innovation and diversity of talent in NOAA-related research and development (OAR lead).
- C Increased number of research students trained on NOAA-related research (OAR lead).

Integrated Global Environmental Observation and Data Management System

NOAA will develop an Integrated Global Environmental Observation and Data Management System based on user requirements and an integrated architecture. NOAA Research will promote international cooperation in developing this system and participate in technology research and development for global observations, particularly meteorological, climate and ocean observations.

Relevant NOAA Performance Measures:

- C Decreased uncertainty in observational measures and elimination of observation gaps, redundancies, and losses to achieve better coverage, timeliness, and reliability, and maintainability of observations for users (OAR supporting).
- C Increased use of other nations' observation platforms, resources, and assets to meet user observation and data management requirements (OAR supporting).
- C Increased number of partnerships that promote international cooperation in global observations and data management programs (OAR supporting).

Homeland Security

NOAA Research provides research, development, and expertise in weather, climate, hydrologic, marine science, solar, and related environmental sciences issues for the United States, its territories, adjacent coastal waters, and to those same areas of cooperating governments, through international agreements. NOAA Research can provide models and forecasts in the event of the release of dangerous particles into the hydrosphere or disruptive solar events to support homeland security. It plays an important role in the collection and dissemination of specialized meteorological and air quality data and to provide expert guidance about air dispersion, marine currents, waves, acoustics, and chemical and biological composition and deposition. NOAA Research seeks to increase forecast capabilities for atmospheric and waterborne dispersion and enhance information technology security by ensuring continuity of service of mission-critical systems.

Relevant NOAA Performance Measures:

- C Improved forecast capabilities for atmospheric and waterborne dispersion (OAR supporting).
- C Improved certainty of continuance of operations for critical NOAA services in the event of national crises (OAR supporting).
- C Enhanced responsiveness to Federal, state, and local requests for support after the release of hazardous materials and during other emergencies (OAR supporting).

Environmental Literacy, Outreach, and Education

NOAA Research participates in NOAA-wide environmental literacy activities focused on educating the US citizenry about the changing Earth, its processes and ecology. NOAA research will improve public awareness of NOAA's mission goals and accomplishments, support increased basic knowledge of the environment, and actively encourage and promote careers in the environmental sciences. NOAA Research will continue to foster the professional development of teachers and scientists throughout their professional lives, encourage students at all levels from varied backgrounds to learn more about environmental sciences and related careers, support many young professionals through a wide range of internships, fellowships and other educational experiences, provide interesting and engaging opportunities for the general public to learn more about the natural world in informal settings, and provide services to a wide variety of professionals working in the natural environment. In addition, NOAA

Research will employ extension techniques and facilitate partnerships as a mechanism to leverage NOAA's outreach capabilities.

Relevant NOAA Performance Measures:

- C Increase the number and diversity of college students graduating each year in fields related to ocean, climate, atmospheric, and social sciences (OAR supporting).
- C Increase the number of M.S.- and Ph.D.- level environmental scientists receiving degrees from minority-serving institutions (OAR supporting).
- C Increase the number of NOAA staff serving as judges for, and NOAA awards presented at, American junior high and high school science fairs (OAR supporting).

International Cooperation and Collaboration

NOAA Research will develop new, and expand existing, strategic international partnerships with national and international organizations to promote programs in climate, atmospheric, and marine research. NOAA Research international activities will be guided by priorities set in the NOAA Strategic Plan and Strategic Plan for NOAA International Activities.

NOAA Research will sustain responsive and timely advisory services to NOAA and its research leadership on international research programs and issues in support of U.S. foreign policy and organizational objectives; expand support for international administrative and operational needs to NOAA Research programs and laboratories; increase the number of new strategic partnerships with national and international organizations that will benefit organizational priorities in climate, atmospheric, and marine research; stimulate new capacity building efforts overseas; and sustain U.S. executive leadership for oceanic and marine science and technology partnerships by administering bilateral agreements.

Relevant NOAA Performance Measures:

- C Increased number of NOAA technical assistance initiatives and capacity-building transfers implemented (OAR supporting).
- C Increased number of organizational objectives achieved through multilateral conferences or bilateral relationships (OAR supporting).

Organizational Excellence: Leadership, Human Capital, Information Technology, and Administrative Services

Sustaining a superior research organization requires an increase to the long-term commitment to research with recruitment of superb scientific talent, financial health, streamlined processes, and state-of-art information technology. NOAA Research is committed to build a strong and diverse workforce, and take steps to offer professional growth opportunities, and ensuring a high quality of work life including telework and e-learning. NOAA Research will promote financial health by raising the nation's awareness of the dangers associated with reduced environmental research capability; working with partners to explore, develop and transfer technologies and information into operations; and building infrastructure capacity to measure, model, and monitor earth systems by maintaining state-of-the-art facilities. NOAA Research will strive to improve IT security to ensure data integrity, and take full advantage of advancing web and telecommunications technology and supercomputing technology to support world class research.

Some of the many activities NOAA Research will support to meet the strategies for Organizational Excellence include:

- C Train senior leadership on safety in the workplace.
- C Encourage participation by senior leadership in the Leadership Competency Development Program for succession planning.
- C Increase the number of facilities with improved co-location of NOAA services and/or strategic partners.

- C Accreditation of IT security program plans.
- C Migration to NOAA Research IT enterprise architecture.
- C Improve coordination and communication through use of web technologies.
- C Increase automation of administrative processes.
- C Improve the timeliness of grant awards.

Relevant NOAA Performance Measures:

1. *Leadership*
2. Human Capital
 - C Complete Human Resources Strategic Plan by the end of FY 2003 (OAR supporting).
3. Facilities
 - C Complete Facilities Management Strategic Plan by the end of FY 2003 (OAR supporting).
 - C Increase number of facilities with improved co-location of NOAA services and/or strategic partners (OAR supporting).
4. Information Technology
 - C Establish security accreditation for mission-critical systems (OAR supporting).
 - C Migration to NOAA IT Enterprise Architecture (OAR supporting).
5. Administrative Programs and Services
 - C Improve customer satisfaction with administrative services (e.g. management of human-resources, grants, procurement, and financial operations) as determined through customer surveys (OAR supporting).

Appendix A: Organizational Description, Abbreviation, and Structure

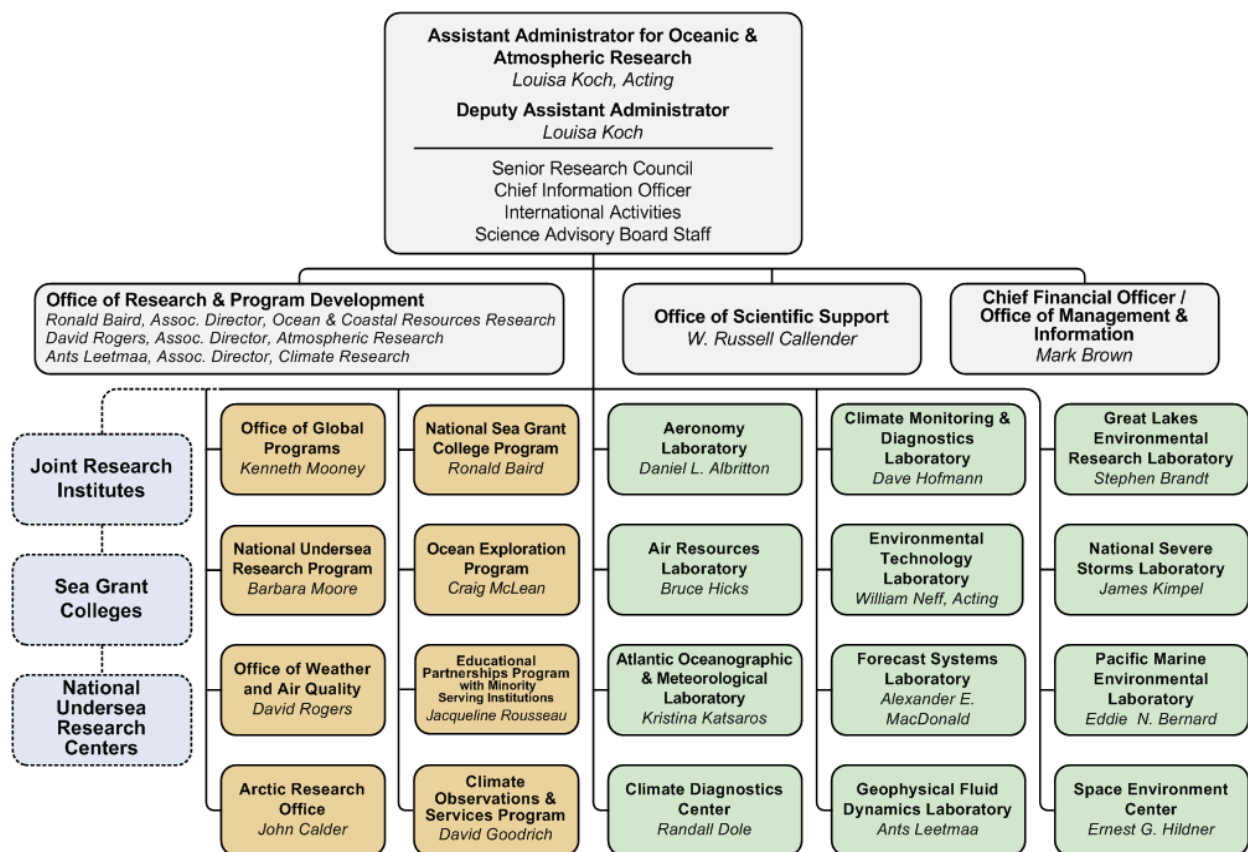
c Organizational Description of NOAA Research:

NOAA is a Federal agency administered by the Department of Commerce. The Department provides policy guidance and resources to NOAA. NOAA Research, a line office of NOAA, is comprised of 12 Federal laboratories and their Joint Research Institute partners, the National Sea Grant College Program, NOAA's Undersea Research Program, Office of Ocean Exploration, Office of Global Programs, Climate Observations and Services Program, Office of Weather and Air Quality, and the Arctic Research Office.

c Organizational Abbreviation:

NOAA Research; Office of Oceanic and Atmospheric Research; "OAR"

c Organizational Chart for NOAA Research:



Appendix B Table 2
Performance Measures as of May 16, 2003

Goal 1: Protect, restore, and manage the use of coastal and ocean resources through ecosystem-based management

Objective A. Protect and restore ocean, coastal, and Great Lakes resources

Strategy: Monitor & Observe

NOAA Performance Measure	Line Office Measure	Baseline	Target
Increased area covered and number of ecological conditions monitored by state-of-the-art observation systems and platforms that provide necessary information for NOAA's stewardship responsibilities	Number of ocean observations and technology available for development of new indicators of climate change and ecosystem health (coral reefs, Arctic, Great Lakes, Tropics)	TBD (2004)	TBD (2004)
Increased area covered and number of ecological conditions monitored by state-of-the-art observation systems and platforms that provide necessary information for NOAA's stewardship responsibilities	Number of technology demonstration projects conducted annually to improve NOAA's ability to collect scientific data	1/year	1/yr
Increased area covered and number of ecological conditions monitored by state-of-the-art observation systems and platforms that provide necessary information for NOAA's stewardship responsibilities	Number of seafloor observations that lead to a better understanding of physical, biological, chemical and geological ocean environmental change	TBD (2004)	TBD (2004)
Increased area covered and number of ecological conditions monitored by state-of-the-art observation systems and platforms that provide necessary information for NOAA's stewardship responsibilities	Number of ocean observations to support the climatic impacts of ecosystem change and the subsequent impacts on fish species and marine mammals	TBD (2004)	TBD (2004)

Strategy: Understand & Describe

NOAA Performance Measure	Line Office Measure	Baseline	Target
Increased ocean and, coastal and Great Lakes areas explored, mapped, characterized, and inventoried	Percent of unique habitats within the U.S. EEZ (estimated 200 sites) mapped, explored, and inventoried.	<5%	20%
Increased number of impacted human communities where sufficient data exist to analyze and understand the economic and social benefits, costs, and impacts of management decisions.	Number of educational mechanisms that promote understanding of economic and social benefits of management decisions	TBD (2004)	TBD (2004)
Increased number of impacted human communities where sufficient data exist to analyze and understand the economic and social benefits, costs, and impacts of management decisions.	Number of workshops involving academia, government officials and local communities that focus on understanding research results and their implication on management decisions	4	15
Increased number of impacted human communities where sufficient data exist to analyze and understand the economic and social benefits, costs, and impacts of management decisions.	Number of peer reviewed publications that advance the science of ocean and Great Lakes research and provide the scientific community with developing state-of-the-art technology	TBD	TBD
Increased number of techniques and tools that can be used to restore and protect ocean and, coastal, and Great Lakes resources	Number of new techniques/mechanisms developed for ecosystem observation systems and networks to provide guidance for ecosystem protection	TBD (2004)	TBD (2004)
Increased number of marine resources potentially available for commercial use (e.g., pharmaceuticals, aquaculture species for human uses)	Number of aquatic species available for commercial use in aquaculture	2	4
Increased number of marine resources potentially available for commercial use (e.g., pharmaceuticals, aquaculture species for human use)	Number of previously undiscovered marine species and compounds identified, analyzed, and understood with promise for medical applications and other benefits for humankind	0	35

Strategy: Assess & Predict

NOAA Performance Measure	Line Office Measure	Baseline	Target
Increased number and accuracy of forecasts of significant ecological events and trends (e.g., harmful algal blooms, coral bleaching, and population shifts)	Increase number/precision of forecasting models for predicting physical, chemical, and biological characteristics of ocean, coastal and Great Lake systems (water levels, wave heights, circulation, invasive species introduction, and climate change)	1	4
Increased number and accuracy of forecasts of significant ecological events and trends (e.g., harmful algal blooms, coral bleaching, and population shifts)	Increase the number of ecosystem and water quality models that incorporate non-point source loadings of nutrients, organic contaminants, and mercury	0	2

Strategy: Engage, Advise & Inform

NOAA Performance Measure	Line Office Measure	Baseline	Target
Increased percentage of coastal communities and coastal inhabitants aware of, and acting appropriately to minimize, their impacts on ocean, coastal Great Lakes resources	Number of developed educational materials, and teacher training to increase the percentage of Americans aware of the oceans, coasts, Great Lakes, and ocean explorations	1	TBD (2005)
Increased percentage of coastal communities and coastal inhabitants aware of, and acting appropriately to minimize, their impacts on ocean, coastal Great Lakes resources	Number of lesson plans produced per year for ocean exploration	40	40/year
Increased percentage of coastal communities and coastal inhabitants aware of, and acting appropriately to minimize, their impacts on ocean, coastal Great Lakes resources	Number of extension resources developed to educate management on human impacts on ocean, coastal, and Great Lake assets	TBD	TBD

Strategy: Manage

NOAA Performance Measure	Line Office Measure	Baseline	Target
Increased number of invasive species under control	Number of cost effective technologies that prevent introductions of aquatic nuisance species via ballast water	1	4
Increased number of invasive species under control	Number of management options for control and prevention of invasive species	TBD	TBD
Increased ocean fisheries production through environmentally sound aquaculture	Number of commercial technologies for offshore aquaculture	2	4

Goal 1: Protect, restore, and manage the use of coastal and ocean resources through ecosystem-based management

Objective C: Rebuild and Maintain Sustainable Fisheries

Strategy: Understand & Describe

NOAA Performance Measure	Line Office Measure	Baseline	Target
Increased number or adequacy of techniques (including stock enhancement) and tools that can be used to restore and conserve fish species	Number of new sampling technologies and models to reduce uncertainties in fish stock assessment	TBD (2004)	TBD (2004)

Strategy: Assess & Predict

NOAA Performance Measure	Line Office Measure	Baseline	Target
Increased Use of physical-biological models for forecasting stock abundance	Number of and improvement of ecosystem models for better Great Lakes fisheries management technology	1	TBD (2005)

Strategy: Engage, Advise & Inform

NOAA Performance Measure	Line Office Measure	Baseline	Target
Increased number of NOAA technologies and techniques that have been transferred for appropriate resource use and managed species conservation to state and local managers, as well as to the public.	Number of new science-based facts that are communicated to fishery managers and fishery management councils to effect policies/regulations on how to maintain healthy fish stocks and rebuild protected species populations	TBD (2005)	TBD (2005)

Goal 2. UNDERSTAND CLIMATE VARIABILITY AND CHANGE TO ENHANCE SOCIETY'S ABILITY TO PLAN AND RESPOND

Strategy: Monitor & Observe

NOAA Performance Measure	Line Office Measure	Baseline	Target
Increased number of long-term observations collected, archived, available, and accessible where random errors and time-dependent biases have been minimized and assessed	Availability of ocean observations for operational products	GTS/Bath avail: 2000/mo; Surface drifters 75,000/mo, WBC time series 800/mo	GTS/Bath avail: 2000/mo; Surface Drifters 90,000/mo, WBC time series 800/mo
Increased number of long-term observations collected, archived, available, and accessible where random errors and time-dependent biases have been minimized and assessed	Number of sustained oceanic and atmospheric observations collected, archived, accessible, and available for operational use	Obs Available: TAO 2100/mo ARGO 2500/mo (2003)	Obs Available: TAO 2100/mo AROG 9000/mo (2008)
Increased number of long-term observations collected, archived, available, and accessible where random errors and time-dependent biases have been minimized and assessed	Number of long line sections completed to monitor change of the uptake and storage of naturally-occurring and anthropogenic carbon dioxide in the oceans	1 (2003)	4?

Strategy: Understand and Describe

NOAA Performance Measure	Line Office Measure	Baseline	Target
Decreased degree of uncertainty of climate system processes, including radiative forcing, in climate forecast products	Document new knowledge of Climate Variability, its impacts on society, or ways to predict it	TBD(2004)	TBD (2004)

Strategy: Assess & Predict

NOAA Performance Measure	Line Office Measure	Baseline	Target
Improved skill of climate variability forecasts	Demonstrate improvement in ranked probability skill score of 6-10 day winter precipitation forecasts in a research mode	0	0.08
Improved skill of climate variability forecasts	Demonstrate skillfull 8-14 day probabilistic forecasts of extreme winter temperature events (upper and lower 10 percent of climatology) in a research mode	n/a	complete (2008)
Improved skill of climate variability forecasts	Demonstrate improvement in ranked probability skill score of 8-14 day winter temperature forecasts in a research mode	0.08	0.15
Improved skill of climate variability forecasts	Demonstrate improvement in ranked probability skill score for wintertime 6-10 day forecasts of U.S. surface temperature in a research mode	.12 (2003)	.26 (2008)
Increased involvement of NOAA researchers and use of NOAA scientific results in national and international assessments	Number of OAR citations in IPCC Working Group I, Climate Science	320 (2001 last IPCC report)	320+ working group chair

Goal 3. SERVE SOCIETY'S NEEDS FOR WEATHER AND WATER INFORMATION**Strategy: Understand & Describe**

NOAA Performance Measure	Line Office Measure	Baseline	Target
Increased number of modeling advances by government and academia demonstrated to improve the NOAA operational prediction suite	Number of parameterizations that demonstrate an improvement over existing operational needs	2 (2004)	10 (2/yr) (2008)
Shortened cycle times from research (government and academic) to operations (e.g., models, technology, and techniques) through the use of testbeds and other methods	Number of joint projects with operational components to move research results and advances in technology into operations	2 (2004)	20 (2/yr) (2008)
Improved accuracy of weather and air quality prediction models.	Increase average tornado lead time of significant (supercell) tornados through the demonstration of improved technology and modeling advances in a research mode	12 min. (2004)	20 min. (2008)
Improved accuracy of weather and air quality prediction models.	Improve 48-hour mean hurricane track forecast error through the demonstration of improved technology and modeling advances in a research mode	130 nm. (2003)	120 nm.
Improved accuracy of weather and air quality prediction models.	Improve 48-hour mean hurricane intensity forecast error through the demonstration of improved technology and modeling advances in a research mode	15.5 kt	14.0 kt
Improved accuracy of weather and air quality prediction models.	Demonstrate skillfull 8-14 day probabilistic forecasts of extreme winter temperature events (upper and lower 10 percent of climatology) in a research mode	n/a	complete (2008)
Improved accuracy of weather and air quality prediction models.	Demonstrate improvement in ranked probability skill score of 8-14 day winter temperature forecasts in a research mode	0.08	0.15
Improved accuracy of weather and air quality prediction models.	Demonstrate improvement in ranked probability skill score of 6-10 day winter precipitation forecasts in a research mode	0	0.08
Improved accuracy of weather and air quality prediction models.	Daily maximum 1-hour ozone concentration forecast error (>120ppb)	30% (2003)	25% (2008)
Improved accuracy of weather and air quality prediction models.	Increase rate of improvement in predictability	TBD (2003)	TBD
Improved accuracy of weather and air quality prediction models.	Demonstrate improvement in ranked probability skill score for wintertime 6-10 day forecasts of U.S. surface temperature in a research mode	.12 (2003)	.26 (2008)
Increased number of new research findings and progress toward their implementation in NOAA operations	Number of diagnostic and process studies conducted to achieve new and improved physical descriptions of weather processes leading to more accurate and extended predictions	TBD	TBD

Strategy: Assess & Predict

NOAA Performance Measure	Line Office Measure	Baseline	Target
Increased use of operational data for verification of and assimilated into weather, ocean, water, and climate prediction models	Cumulative number of new data assimilation techniques evaluated	TBD (2004)	TBD (2008)
Increased volume of forecast and warning information formatted to clarify the uncertainty of an event (e.g., space weather, air quality, water and weather forecasts)	Cumulative number of models/products transitioned into space weather operations	1 (2004)	12 (2008)

Strategy: Engage, Advise & Inform

NOAA Performance Measure	Line Office Measure	Baseline	Target
Increased number of communities with plans in place to act on weather warnings and to reduce the impacts of coastal hazards	Number of tsunami-threatened communities for which inundation maps are available	130 (2003)	200
Increased assistance to international partners to improve response capabilities to weather and water predictions	Number of international scientific visits or exchanges in OAR labs/programs	18 (2004)	18 (2008)

Goal 4. SUPPORT THE NATION'S COMMERCE WITH INFORMATION FOR SAFE, EFFICIENT, AND ENVIRONMENTALLY SOUND TRANSPORTATION**Strategy: Understand & Describe**

NOAA Performance Measure	Line Office Measure	Baseline	Target
Shortened cycle time from research (government and academia) to operations (e.g. new techniques, improved products)	Number of joint projects with operational components to move research results and advances in technology into operations	TBD (2004)	TBD (2008)
Development of viable alternatives to ballast water exchange to prevent the introduction of exotic species to U.S. coastal waters	Number of cost effective technologies that prevent introductions of aquatic nuisance species via ballast water	1	4